

Remarks:

This amendment is submitted in an earnest effort to advance this case to issue without delay.

The specification has been amended to eliminate some minor obvious errors. No new matter whatsoever has been added.

The claims have been wholly rewritten so as to more clearly define the invention over the art and to better comply with US claiming style. No new matter whatsoever has been added; instead the two main claims now include, among others, limitations from canceled dependent claims.

Before going into a detailed discussion of the prior art, it is important to explain why the "single-valued projections" from the prior art, e.g. from Karella, are different from the multi-valued projections of the present application.

More particularly, due to their high energy, gamma quanta or x-rays cannot be deflected by a lens system, such as is known from optical photography, in order to obtain images. Gamma quanta or x-rays are instead imaged with collimators made, e.g. of lead. The incident rays cannot be deflected thereby, instead only those rays that come from admissible directions are filtered out by means

of the collimators from the plurality of rays arriving from various angles.

Gamma quanta or x-rays, in contrast to visible light, can penetrate objects. This fact is utilized, e.g. in x-ray images in which the x-rays travel in one direction from the source to the x-ray film through the object lying between them and are thereby weakened to a different extent. In contrast, in nuclear-medical tests the source is moved inside the body as a local concentration of the radiating radionuclide. Moreover, a plurality of sources is involved here. In both cases, however, the gamma quanta or x-rays penetrate the object and thus provide depth information or volume information on the object. Mathematically this depth information is generally described as a line integral. Line integrals virtually "collect" the object information along the beam passing through the object.

The registration of the gamma quanta or x-rays is carried out on a two-dimensional detector. The projected image obtained is therefore two-dimensional; it is called a projection and due to the high-energy nature of the radiation contains depth information on the object.

Starting from the viewing angle of the projection pixels and image elements, a distinction must be made between a single-valued projection and a multi-valued projection. Single-valued projections are characterized in that precisely one beam passing through an object belongs to each image element of the projection.

A simple example is the parallel (multiple) hole collimator used in nuclear medicine. Essentially this is a lead plate that is placed in front of the radiation-sensitive detector. A large number of very fine parallel bores are made in this lead plate. The arriving radiation is imaged without being absorbed by the lead only when it passes through the collimator, passing exactly along the bores. Nonparallel alignments of the holes is also conceivable, e.g. with magnifying images by fan geometry or cone geometry. A completely different type of collimation through a single-pinhole collimator is also conceivable. The conical beam bundle on the object and detector side, which beam bundle can enter into and exit from the hole, adheres to a requirement defining the single-valued projection, according to which requirement only one single beam passing through the object is associated with an image element of the projection.

However, in the case of multi-valued projections, such as are formed by the overlap of multi-pinhole projections, this restriction is not followed. Image elements of the projection now collect information not only from one beam direction, but simultaneously from several beam directions. If all detectable beams of a collimator of this type are combined, it is evident that they overlap (as shown in FIG. 1 at 7). In case of an overlap, a projection image point carries depth information of the object from completely different directions. This advantageous increase in

information becomes worthless if no method is known for unscrambling and evaluating this multiple information again.

Based on the present invention, it is precisely this evaluation and unscrambling that is carried out in the course of the tomographic reconstruction.

US 6,445,767 of Karellas does not disclose a T-SPECT tomograph as defined by the invention, i.e. does not disclose a multi-pinhole collimator with tilted holes and only a few, e.g. 7 to 14, holes. Karellas discloses a system for a detector technology for digital x-rays. Karellas utilizes a flat scintillation crystal for converting x-ray radiation or gamma radiation into visible light. The luminance occurring at specific locations of the flat crystal is imaged on one or more CCD sensors via refracting optical systems or optical fibers (with or without interposed light amplifiers) (see abstract). Furthermore, Karellas describes the use of a flat detector made of amorphous silicon, which, if necessary, should replace the CCDs and/or the scintillation crystal). A T-SPECT device with multi-pinhole collimator carrying out translational movements is not mentioned. Translational movements, which are carried out in Karellas with "overlap" (column 24, line 47) serve a completely different purpose. They are provided only to achieve a total flat fluoroscopic image of an object that cannot be imaged at one time due to the small viewing field of the camera. The overlap

mentioned therefore serves in Karellas to place the individual images next to one another. These individual images always have the character of a single-valued projection of the object. No multi-pinhole collimator for collecting expanded depth information is present.

This is in contrast to our new claims 19 and 27, according to which the object, or certain parts thereof, is projected by several suitably positioned and tilted pinholes, namely such that the projections associated with the individual pinholes overlap on the detector and do not meet the requirements of single-valuedness.

With respect to paragraph 7 of the Office Action relating to the use of a multiplexed multi-pinhole collimator, the examiner is incorrect in his interpretation of the information from Karellas. The examiner states that this use is seen in Karellas, column 16, lines 51 through 53. This is an error. In fact, for the emission imaging Karellas proposes a single-pinhole collimator (see FIG. 11) and a "multi-hole type collimator (see FIG. 22A and 22B)" that is, a multi-holed collimator. Based on the images that Karellas produces, he means a parallel-hole collimator or a focusing collimator such as, for example, a fanbeam collimator or a conebeam collimator. In any case, Karellas does not disclose a pinhole collimator with many holes that are arranged such that overlapping is desired, that is, not a multi-pinhole collimator.

GB 1,184,304 of Anger does not disclose a T-SPECT as defined by the invention. In FIG. 3 (and not as described in FIG. 2, see paragraph 8 of the Office Action), in conjunction with lines 23 through 46 on page 2 Anger discloses a collimator, namely a focusing collimator and not a multi-pinhole collimator with, e.g. 7 to 14 holes. Since only one cutting plane is shown, it is open whether this is a conebeam collimator or a fanbeam collimator. Under any conditions it is always a collimator imaging in a single-valued manner in a simple projective manner, and not a multi-pinhole collimator for obtaining greatly expanded depth information encoded by the overlap, as is described in our application.

US 4,144,457 of Albert discloses a device for detecting x-ray radiation where the object can also be displaced relative to the stationary detector. The detector 29 and the x-ray source 28 are thereby rotated about the object 21, see FIG. 2, column 5, lines 44ff. There is no further disclosure regarding a T-SPECT with multi-pinhole collimators and axially/transaxially tilted holes in Albert. In particular, an evaluation method according to new claim 9 cannot be derived from this document.

US 4,419,585 of Strauss does not disclose a T-SPECT as defined by the invention either, but again discloses only a multi-hole collimator, that is a multi-hole collimator that has a plurality of identically tilted but otherwise parallel holes (see

FIG. 2 and column 4, lines 1 through 14). Again, this provides only single-valued projections.

An overview of the apertures can be seen, e.g. in US 5,245,191 of Barber. See FIGS. 1 through 4 and column 2.

The difference between the multi-hole collimators of documents Albert, Anger, Karellas and Strauss and the multi-pinhole collimator of this invention is that expanded depth information is obtained with a multi-pinhole collimator as in the present application, see below.

None of the documents cited above from the first Office Action discloses a multi-pinhole collimator. The subject matter according to new claims 19 and 27 is therefore new with respect to Karellas, Anger, Albert and Strauss.

With respect to document DE 101 42 421 A1 "SPECT examination device" (US equivalent 7,199,371 cited in attached PTO-1449) it should be pointed out that this is the only document cited by the examiner which comprises a multi-pinhole collimator, that is a perforated plate as an aperture, which, in contrast to the multi-hole collimators cited above, has only comparatively few holes, which taper conically and are positioned randomly and tilted, such that they cover a specific object volume by "overlap" and via which the gamma quanta are projected onto the detector surface.

With the reconstruction method cited in US 7,199,371 (claims 6 and 12), the information from the plurality of the individual projections associated with the respective pinholes is evaluated, which projections overlap to better utilize the detector and thus are additionally encoded, so that a high sensitivity and resolution is obtained (column 2, lines 58ff "provides the advantage of a high positional resolution. Accordingly a device with good positional resolution and good sensitivity is provided . . .").

However, commonly owned US 7,199,371 relates to a rotation SPECT ® SPECT). See the passage: "wherein the detector together with the collimator is moveable around a holder..." in claims 1 and 6 and in paragraph [3] of commonly owned DE 101 42 421. The R-SPECT does not perform a translational movement relatively between a support and the detector.

The subject matters according to the new claims are thus also new compared to US 7,199,371 or DE 101 42 421. Novelty of the device and of the method is thus given with respect to all of the cited prior art. Regarding Barber see immediately below.

The closest pertinent prior art is US 7,199,371 that is commonly owned with this application. Only US '371 discloses a multi-pinhole collimator with randomly positioned and tilted pinholes and thus a comparable aperture system.

All of the other documents cited in the Office Action disclose either the cited multi-pinhole collimators or collimators with precisely one hole (Karellas, FIG. 11) and thus always produce only a single-valued image of the object marked with radiopharmaceuticals, which has nothing to do with the present invention. None of these printed patents discloses an intended "overlap" with expanded depth information based on a multi-pinhole aperture. These documents are therefore not pertinent prior art.

In fact, US 7,199,371 is the closest pertinent prior art. The difference essential to the invention from our further development is shown below, the present T-SPECT application.

In the closest pertinent prior art, that is, in US 7,199,371, an intended overlap is mentioned, but in connection with R-SPECT. Our present application differs from this through T-SPECT and transaxially or axially tilted holes (in new claim 19) and through a reconstruction method (in new claim 27) that, according to paragraphs [68] through [72] and claim 16, previous version, always takes into consideration the position of the object to the detector and the tilt and the geometry of the pinholes.

This difference from R-SPECT means that improved depth information, even from an object that is difficult to access, is obtained with simultaneously simpler apparatus design.

More particularly, improved depth information can be easily derived based on comparison of FIG. 3a and 3b [89]. Objects that are difficult to access cannot be examined by R-SPECT, for

example, when the patient's shoulders hamper accessibility (e.g. when examining the thyroid gland). And the T-SPECT is simpler in design since rotating cameras are very difficult to handle for exact positioning, see [13].

The objective, technical object of the invention is therefore to provide a SPECT of simpler design compared to R-SPECT and the other prior art, for an overlapping multi-pinhole projection (3-D projections), which SPECT compared to the R-SPECT variant does not lead to information losses with the depth localization of the tracers in the object difficult to access. The technical object has also been to provide a corresponding SPECT method that is able to provide reproducible 3D projections even of an object that is difficult to access and of radiopharmaceuticals distributed therein with a simplified apparatus design compared to R-SPECT and to evaluate the provided encoded 3D projections with an iterative reconstruction algorithm in order to calculate the three-dimensional volume data record of the radionuclide distribution.

US 7,199,371 does not give any hint to one skilled in the art searching of the inventive solution of the problem faced here, namely a simplified apparatus design without loss of the depth information. There is no mention anywhere that the objective technical problem can be solved through a T-SPECT with transaxially or axially tilted holes in connection with a method that takes into consideration the position of object to detector and the tilt and geometry of the pinholes.

US 7,199,371 mentions only R-SPECT, see claims 1 and 6: "moving the camera" or "whereby the camera is moveable around the holder (note: with the object)."

Above all, there is no mention anywhere that qualitatively even better images can be provided with the simplified apparatus design of the T-SPECT. Compared to R-SPECT, the T-SPECT namely already supplies improved depth information with only one single detector, since R-SPECT leads to artificial images, see FIGS. 3a and 3b and paragraph [89].

Compared to US 7,199,371, the present application is therefore to be deemed clearly based on an inventive step.

The examiner's attention is directed to a publication of the inventors here, namely "High-Resolution SPECT using Multipinhole Collimation," ("IEEE 2003"). IEEE2003 dates from June 2003 and is prior to the filing date of this application.

In the IEEE2003 in addition to the R-SPECT (see FIG. 2 and III. MULTIPINHOLE VERSUS SINGLE-PINHOLE, first paragraph: "ROR" = radius of rotation: this is therefore clearly a rotating camera) a "tilted axis" in the pinhole (see FIGS. 1 and 3) is also mentioned. Likewise disclosed a transaxial or axial tilting of the pinhole, see page 315, left column, I. Introduction, second paragraph. The T-SPECT is not disclosed.

One skilled in the art in search of the solution according to the invention to the objective, technical problem,

namely a simplified apparatus design without loss of the depth information in the object difficult to access, is not given any hint by IEEE2003 with R-SPECT of the solution according to the invention of the objective, technical problem. The solution according to the invention provides working exclusively with T-SPECT (that means the object is moved relative to the detector only in the X/Y direction) and transaxially and/or axially tilted holes and carrying out a method that takes into account the position of object to detector and the tilt and the geometry of the pinholes. Surprisingly depth information can thus be obtained as with R-SPECT and better (FIGS. 3a and 3b).

Completely surprisingly, improved depth information was obtained from the object marked with radiopharmaceuticals with much simplified apparatus design at the same time. For T-SPECT with a detector that is displaceable in the X/Y direction is a much simpler design than R-SPECT with rotating gamma cameras. Just consider the weight of a single camera, which can be up to 100 kg, alone and the resulting problems with the exact positioning with respect to the object. It was not to be expected that with T-SPECT and deviation from the prior art (R-SPECT) even more usable results could be achieved with multi-valued projections.

By no means can a hint of a simplified apparatus design with T-SPECT be derived from IEEE2003. Then only in connection with an evaluation taking into account the positions of the object to the detector and the tilt and the geometry of the pinholes (new

claim 9) is a T-SPECT sufficient to realize a simpler apparatus design and at the same time to thereby obtain the depth information as with an R-SPECT and even better (FIGS. 3a, 3b). Not a single passage in the IEEE2003 indicates this connection.

Not until T-SPECT device according to the invention and the new method has it also been possible to examine objects that are not accessible from all sides, such as, e.g. thyroid glands. In addition to the simpler apparatus design of T-SPECT compared to R-SPECT, this is a further clear indication of the inventive achievement of inventors, since it has hitherto not been possible to reconstruct objects of this type in a high-quality manner with respect to the depth information even with conventional R-SPECT, as described in IEEE2003 (FIG. 3a, FIG. 3b).

This imaging approach is possible since surprisingly sufficient angle and depth information can also be collected with the multi-pinhole aperture with T-SPECT according to device according to the invention and method in order to be able to perform a tomography. We can provide proof that the T-SPECT thereby provides comparable tomographic reconstruction results to R-SPECT. We can also prove that new T-SPECT device and the method are advantageous compared to R-SPECT. Namely compared to R-SPECT T-SPECT shows no artifacts in the reconstruction of the radiopharmaceuticals along the axial extension of the object. These artifacts are demonstrably present with R-SPECT and lead to

falsification in the reconstruction of the radiopharmaceuticals in the object.

The device and the method according to new claims 19 and 27 is therefore inventive compared to the combination of US 7,199,371 B2 and IEEE2003.

The result is no different for one skilled in art when combined with Barber. Barber does not give any indication of a transaxial and/or axial tilt of the pinholes. A method in which position information and tilt and geometry of the pinholes are used is not mentioned either. There is certainly no indication of a useful utilization of this information in connection with or for a T-SPECT. And Barber certainly does not give any indication that these process steps and device features could be connected to a simpler apparatus design by means of T-SPECT. Therefore the information content of this printed patent is likewise worthless for one skilled in the art.

In contrast to present application and also, by the way, to US 7,199,371, Barber even explicitly state that "another objective of the invention is a tomographic apparatus that yields the desired level of spatial resolution with no overlapping or with greatly reduced overlapping thus simplifying the complexity required for the corresponding reconstruction algorithm ..."

In contrast herewith in the present application through the device according to the invention with transaxially and/or

axially tilted holes and T-SPECT and consideration of position between object and detector, additional depth information is obtained that is sufficient for a 3D-reconstruction, even if "only" one T-SPECT is carried out.

One skilled in the art in search of the solution to the objective technical problem would certainly not consult the art cited by the examiner, since they all disclose single-valued projections and thus teach away from the desired multi-valued 3D projection with expanded encoded depth information. If one skilled in the art were nevertheless to review the informational content of the cited documents, he/she would learn that, in addition to what has been stated above:

Karellas operates a completely different method and a completely different device. The method leads to single-valued projections, but to 3D projections. This is a fundamental difference overlaps lead I) to an initially uninterpreted image and ii) to an inherent collection of multi-angled information from different depth layers of the object. Further "encoded" depth information is collected through the acquisition of further images of this type at a detector position respectively displaced in an x/y plane. In this application this is mentioned on page 2, para. 0030. This information is ultimately evaluated by a computer program in the form that the tomographic 3D object (to be more exact, the 3D distribution of the radionuclide inside the object) itself is calculated. In contrast thereto the type of displacement

of the detector, as proposed by Karellas, see column 22, lines 31-39 and FIG. 22A/B, is used in order to enlarge the restricted viewing field of the detector. In arranging individual images next to one another, he thus obtains an image with larger viewing field. The same applies to Anger, Albert and Strauss.

If the examiner continues to take the view that these documents and Karellas in particular, are essential to the invention, he should explain why he considers these single-valued projections, which serve only to arrange individual images next to one another, to be relevant, even though demonstrably no depth information can be obtained as with T-SPECT.

Not until the solution according to the invention has it been possible to achieve a clear scientific leap both with respect to the prior art cited by the examiner, which is concerned only with single-valued projections, and with respect to document the other art discussed above, including the documents from Schramm and Barber. The rejections under §102 and §103 are clearly overcome.

If only minor problems that could be corrected by means of a telephone conference stand in the way of allowance of this

case, the examiner is invited to call the undersigned to make the necessary corrections.

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